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Soil Survey of Iowa, Report No. 5—Lee County

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

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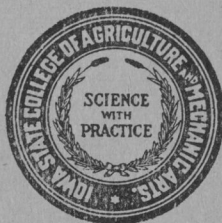
SOIL SURVEY OF IOWA

Report No. 5---LEE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils



Soil Survey Report No. 5

September, 1918

Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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- 1 Bremer County
- 2 Pottawattamie County.
- 3 Muscatine County.
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- 5 Lee County.
- 6 Sioux County.

September, 1918.

Soil Survey Report No. 5

SOIL SURVEY OF IOWA

Report No. 5--LEE COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of M. E. Sar and G. E. Corson



One of Lee county's soil types — Putnam silt loam

IOWA AGRICULTURAL
EXPERIMENT STATION

C. F. Curtiss, Director

Ames, Iowa

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LEE COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of M. E. Sar and G. E. Corson

Lee county is situated in the extreme southeastern corner of Iowa partly within the Mississippi loess soil area and partly in the southern Iowa loess area. Almost 80 percent of the soils of the county are loess soils, the other types being terrace and bottomland soils.

The county comprises an area of 511 square miles or 327,040 acres, of which 265,299 acres or 81.1 percent is in farmland, the number of farms being 1,870 and the average size of the farms 141.9 acres.

The following figures taken from the 1916 Iowa Yearbook of Agriculture show approximately the utilization of the farm land of the county:

Acreage in general farm crops.....	125,270
Acreage in pasture.....	123,680
Acreage in orchards.....	1,889
Acreage in gardens.....	589
Acreage in farm buildings, feed lots, and public highways.....	7,908
Acreage in crops not otherwise listed.....	1,287
Acreage in waste land.....	6,489

Many of the farmers of the county are engaged in general farming, and the livestock industry is of considerable importance. Hogs, sheep and goats are raised in considerable numbers and the dairy industry is developing rapidly. Cattle are also fed and fattened for market to some extent. Truck crops are grown on certain areas in the county, especially on the sandy terrace soils and they prove quite profitable. The methods of soil treatment and systems of permanent fertility recommended for livestock and general farming conditions are not applicable to truck farming. Altho experimental work dealing with individual truck crops has not been carried out in Lee county, recommendations for the treatment of particular soils adapted to truck crops may be given. General information regarding the growing and handling of truck crops may be secured from the Truck Crops Section of the Iowa Agricultural Experiment Station.

The area of the waste land in the county is large and methods for its reclamation and utilization should be adopted. General recommendations along this line cannot be given, for the treatments necessary vary widely in different cases. Later in this report treatments are given for individual soil types. Further specific information for special cases may be secured from the Soils Section of the Agricultural Experiment Station.

The farm crops grown in Lee county in the order of their importance are corn, hay, oats, wheat, rye, potatoes, alfalfa and barley. The yields and value of these crops in Lee county are shown in table I.

Corn occupies the largest acreage of all the farm crops in the county, and its value is equal to that of all the other crops combined. It is used largely as a feed for livestock altho considerable amounts are sold outside of the county. The average yields secured are about 40 bushels per acre altho much larger crops are grown in favorable seasons. The dark colored upland soils in the northwestern part of the county generally give the largest yields.

TABLE I. THE ACREAGE YIELDS AND VALUE OF CROPS GROWN IN LEE COUNTY

	Acres	Percent of total farm land in county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	56,200	21.18	26	1,461,200	\$.81	\$1,183,572
Oats	19,100	7.19	23	439,300	0.49	215,257
Spring wheat			12	1,000	1.54	1,540
Winter wheat	9,200	3.46	14	128,800	1.58	203,504
Barley	340	.12	26	8,800	.90	7,920
Rye	6,500	2.45	17	110,500	1.15	127,075
Potatoes	1,160	.43	51	59,200	1.75	103,600
Tame hay	32,200	12.13	1.6	51,500	9.00	463,500
Wild hay	20		1.5	30	7.89	237
Alfalfa	550	.20	3.2	1,760	11.71	20,610
Pasture	123,680	46.58				

The crop of next importance in the county is hay, tame hay far exceeding wild hay in acreage, yield and value. The tame hay, as a rule is made up of timothy and clover and this combination makes an excellent quality hay and generally gives quite satisfactory yields. Clover is grown successfully on many of the soils and yields average one and one-half tons of hay per acre. Timothy is sometimes used alone for hay and gives good yields.

Oats comes next to hay in acreage and production, and is an important crop in the county. Practically all the oats produced is fed on the farms and very little is sold out of the county. The yields secured average 25 to 40 bushels per acre with occasional higher yields in particularly favorable seasons.

Both winter and spring wheat are grown largely as a money crop in Lee county. The acreage devoted to winter wheat, far exceeds that used for spring wheat, the yields of the winter varieties averaging about 20 bushels per acre which is somewhat greater than the average for the spring varieties.

Rye is of considerable importance in the county and yields of 40 bushels per acre have been reported. Both wheat and rye seem better suited to the light colored bluff soils than the darker upland soils.

Alfalfa is being grown more extensively each year, three or four cuttings usually being obtained with average total yields of 2½ to 3 tons of hay per acre. It is best suited to the silt loams, loams and sandy loams and is becoming a very valuable crop.

Among the truck crops grown on the sandy terrace soils are strawberries, watermelons, sweet potatoes and tomatoes. In good locations and in favorable seasons excellent yields of all these crops are secured, sweet potatoes, for example, sometimes yielding as high as 250 bushels per acre.

The livestock industry in Lee county is varied. The following figures taken from the Iowa Yearbook for 1916 indicate its extent.

Horses (all ages).....	11,033
Mules (all ages).....	740
Swine (July 1, 1916).....	35,502
Cattle (cows and heifers kept for milk).....	9,322
Cattle (other cattle not kept for milk).....	18,234
Cattle (total, all ages).....	27,556
Sheep (all ages, on farms).....	20,359
Sheep (shipped in for feeding).....	1,605
Sheep (total pounds wool clipped).....	126,227

It is apparent from these figures that the growing of cattle, swine and sheep is especially important. The livestock industry is profitable and with

¹ Iowa Yearbook of Agriculture 1916.

the excellent bluegrass pastures of Lee county, should undoubtedly be developed to a much greater extent than is the case at present.

The value of land in Lee county ranges from \$40 to \$200 per acre. The Buckner fine sand occurring in the eastern and southwestern part of the county is perhaps the poorest soil in the county owing to its lack of fertility and its tendency to blow. It is not well adapted to the common farm crops and is very susceptible to drought.

While the yields of crops in Lee county are generally good, experiments indicate that proper methods of soil treatment and management will increase the productivity of the soils and make them permanently fertile.

The soils are generally acid in reaction and applications of lime should be made whenever necessary to secure a satisfactory growth of crops, especially alfalfa and clover. Organic matter is present in most of the soils of the county in considerable amounts but applications of farm manure have proven very valuable and either this material or green manure is necessary to keep the soils satisfactorily productive. Phosphorus fertilizers do not always prove profitable at the present time but they will undoubtedly be required in the future and they might be of value in some cases at the present time. For truck crops artificial fertilizing materials are often very valuable and complete commercial fertilizers may often be employed with profit for certain truck crops. Crop rotations should, of course, be followed in all cases. This is just as true in the case of truck farming as in the growing of general farm crops. Drainage is necessary in some cases but in general the soils of the county are well drained.

THE GEOLOGY OF LEE COUNTY¹

The underlying rock material in Lee county consists of limestones, sandstones and shales. Over the surface of these rocks which were much eroded, the glacial deposits were spread. The depressions were all filled by these deposits and the rock material covered to a considerable depth. Only where streams have cut thru the drift material has there been any exposure of the underlying rocks. A rather even plain having a general southward slope was thus formed by the glacial drift. The underlying rocks were buried so deeply that their effect on the soils of the county is not important and attention may be centered on the surface deposits.

The lower portion of the glacial deposit consists of a blue boulder clay, varying from a few feet to 200 feet in thickness overlaid by a yellow clay from 30 to 75 feet in depth. The blue boulder clay is made up of blue clay filled with boulders of various kinds. At some places on the higher levels, this clay layer is thin or absent but it generally fills the depressions in the underlying rocks. In the old channel of the Mississippi it has a thickness of fully 200 feet and at various other places it occurs in considerable thickness. The yellow clay which rests upon the blue also carries boulders of various sizes, many of which are of limestone. Occasionally a layer of sand is found separating the blue and yellow clays as is the case at the "yellow banks" on the Des Moines river, where the sand layer is 25 feet in thickness. The yellow clay usually contains considerable sand and where it joins the overlying loess it is

¹ Keyes-Iowa Geological Survey Vol. III, 1895, p. 356.

generally changed to a brownish or reddish-yellow color. Frequently a line of pebbles also marks the separation point of the clay from the loess covering.

The entire layer of drift is more or less completely buried under a loess covering which varies in thickness from a few feet up to 15 feet. This loess consists of a fine silt varying in color from gray-white and light brown to dark brown and black. It is believed to have been formed by the deposition of wind-blown material at some previous geological time, a belief which is strengthened by the rather uniform distribution of the material over the drift or glacial till.

Well marked terraces occur in the alluvial plains along the Mississippi and Des Moines rivers at some places having an elevation of 50 feet. They are composed of alluvial material deposited by the rivers at some previous time and the areas which they cover have been raised above the zone of flooding by the gradual deepening of the river channels due to the decrease in volume of water carried by the rivers. The soil material on these terraces is, therefore, quite variable in composition.

It is evident that the drift, the loess and the mixed alluvial material of the terraces are the sources from which the soils of the county are derived, the only exception being in the case of a small area of a residual limestone soil which is of no importance agriculturally.

PHYSIOGRAPHY AND DRAINAGE

Lee county occupies a broad upland plain, the surface of which is for the most part slightly undulating to rolling. At the border of this plain there is a sudden drop of 200 feet or more to the water-level of the streams bordering the county and numerous steep ravines and deep gorges occur.

This upland area slopes gradually toward the southeast and is divided roughly by Big Sugar creek and Sugar creek into two wide areas with a narrow strip of higher land between. The Chicago, Burlington and Quincy railroad closely follows this ridge of higher land. The areas between these two creeks and Skunk river on the north and Des Moines river on the south are somewhat elevated above the wide, shallow areas of Big Sugar and Sugar creeks but they are very irregular and much cut up by small streams.

Low-lying, alluvial plains always border the small streams but none of them are very extensive in area. Along the Mississippi, however, there is a rather large area of bottomland lying between the mouth of Skunk river and Fort Madison including a large portion of Green Bay township. In the area lying between Fort Madison and Montrose there is also some bottomland but there the elevation is somewhat greater and well defined low terraces occur. Near Sand Prairie on the Des Moines river there is an important area of terrace soil separated by a narrow strip of bottomland from the river. With these exceptions the uplands meet the Des Moines and Mississippi rivers with sharp bluffs which are high, steep and occasionally rocky.

The drainage of Lee county is accomplished by three creeks, two of which, Sugar and Big Sugar, are large while the third, Lost creek, is much smaller. These creeks rise in the northwestern part of the county and flow in a southeasterly direction emptying into the Des Moines river on the south or the Mississippi on the east border of the county. The northeastern border of the county is formed by Skunk river which also empties into the Mississippi.

Smaller streams or branches of these creeks and rivers complete the drainage system of the area.

The drainage of the county by means of these streams and their tributaries is on the whole very satisfactory as is shown in the accompanying map. The upland soils are usually not in need of artificial drainage. The bottoms along the Mississippi river and smaller streams are on the contrary very apt to be too wet for cultivated crops and they are so low that their drainage is difficult if not quite impossible. In many cases also the soil is subject to overflow. A general consideration of the importance of drainage is given later and it may merely be mentioned here that an efficient natural drainage system is a long step toward the securing and maintaining of the fertility of any soil.

THE SOILS OF LEE COUNTY

There are four general classes of soils in Lee county, loess, terrace, swamp and bottomland and residual soils. Loess soils are deposits of wind carried material made when the climatic conditions were somewhat different than at present. Terrace soils are accumulations of drift and alluvial materials deposited on the banks of streams and now located above the flood plains of the present rivers due to the decrease in the volume of the streams

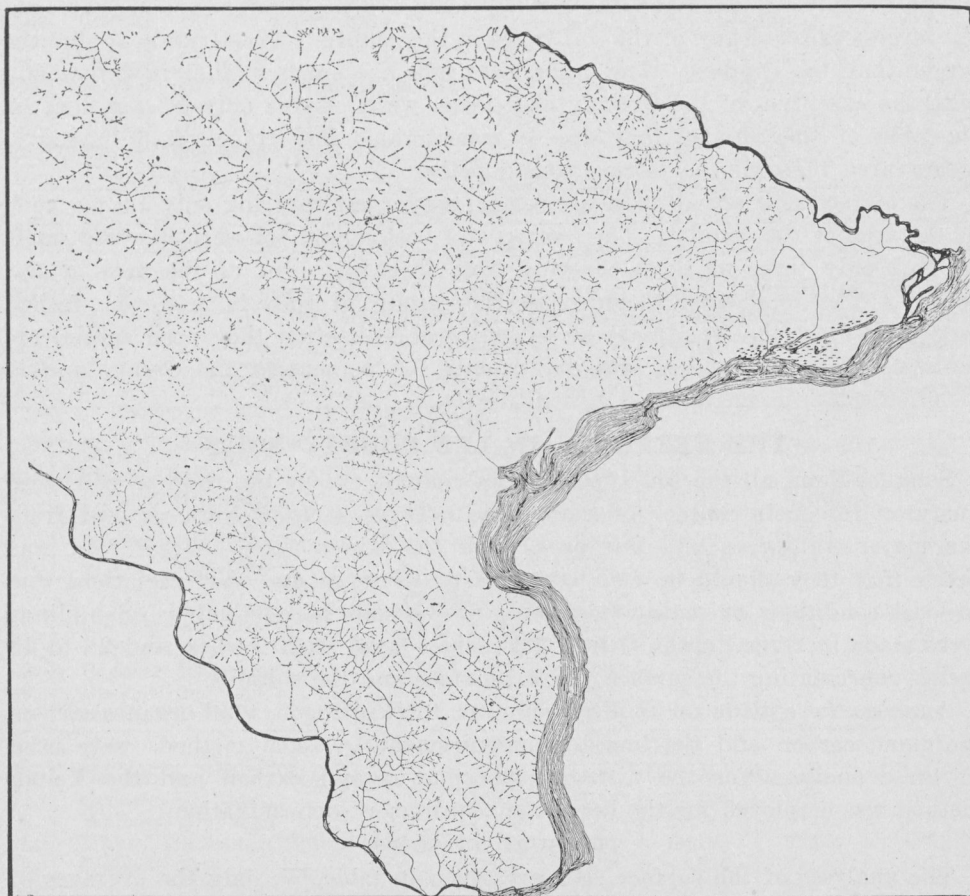


Fig. 1. The natural drainage system of Lee county

and the consequent lowering of the river channels. Swamp and bottomland soils are those occurring in low-lying, undrained areas or bordering on streams and subject to overflow by the rivers during flood seasons. They are largely composed of alluvial material and hence are quite variable in composition. Residual soils are those formed by the various weathering agencies from the underlying rock and which remain resting on some of the same rock material from which they were formed.

The distribution of the soils of Lee county among these four classes is shown in table II.

Nearly 80 per cent of the county is covered by loess soils. The terrace and swamp and bottomland soils occupy much smaller areas and there is one residual soil in the county which is of very minor importance.

With the exception of one loess soil and one terrace soil, all the loess and terrace soils in the county are slightly rolling in topography. These exceptions are the Grundy clay loam and the Buckner silt loam, both of which are level. The residual soil, the Union stony loam, is rather rough.

There are six loess soils, five terrace soils, eight swamp and bottomland soils and one residual soil in Lee county. The relative extent of these various types in the county is shown in table III.

The Grundy silt loam and the Lindley loam are the chief loess soils covering the largest areas of any of the soil types in the county. The Grundy is slightly larger than the Lindley. The other loess soils are much smaller in extent but with the exception of the Grundy clay loam, which covers only 0.5 per cent of the area of the county, they are of considerable importance each having a larger area than all the terrace soils together.

The terrace soils are all of small extent, the largest covering only 1.9 per cent of the area of the county. The swamp and bottomland soils are likewise small in area only three of them covering over three per cent of the area of the county. The total area included in this group of soils is, however, rather large and from the standpoint of agricultural utilization they need special attention. The one residual soil covers only 0.7 percent of the county and is of practically no importance agriculturally.

THE FERTILITY IN LEE COUNTY SOILS

Samples from all the soil types in Lee county, except the residual soil were analyzed for their content of plant food. Three samples were secured from the major soil types and one each from the minor types. Great care was taken that they should be representative of the type and that variations due to local conditions or recent treatments of the soils be eliminated. Samplings were made at three depths, 0 to 6 2-3 inches, 6 2-3 to 20 inches, and 20 to 40 inches representing the surface, the subsurface and the subsoils.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and the limestone requirement. Official methods were used in these analyses for the nitrogen, phosphorus and carbon and the Veitch method was employed for the limestone requirement determination.

THE SURFACE SOILS

The analyses of the surface soils are given in table IV, only the averages of the various determinations on the same soil types being included. Duplicate

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS, LEE COUNTY

	Acre	Percent
Loess soils	260,736	79.8
Terrace soils	20,224	6.1
Swamp and bottomland soils	43,648	13.4
Residual soils	2,432	0.7
Total	327,040	...

TABLE III. AREAS OF DIFFERENT SOIL TYPES, LEE COUNTY

Soil	Soil Types	Acre	Percent
LOESS SOILS			
64.	Grundy silt loam	89,920	27.5
65.	Lindley loam	77,568	23.7
66.	Putnam silt loam	37,184	11.4
31.	Memphis silt loam	32,576	10.0
67.	Marion silt loam	21,760	6.7
68.	Grundy clay loam	1,728	0.5
TERRACE SOILS			
36.	Buckner silt loam	6,272	1.9
69.	Buckner very fine sandy loam	4,288	1.3
45.	Buckner fine sandy loam	3,392	1.0
46.	Buckner fine sand	3,392	1.0
38.	Buckner loam	2,880	0.9
SWAMP AND BOTTOMLAND SOILS			
70.	Genesee very fine sandy loam	11,136	3.4
71.	Genesee silt loam	10,368	3.2
26.	Wabash silt loam	5,056	3.1
26a.	Wabash silt loam (colluvial phase)	5,120	
72.	Wabash clay	5,184	1.6
48.	Wabash silty clay loam	4,096	1.3
62.	Wabash fine sandy loam	1,920	0.6
49.	Wabash loam	768	0.2
RESIDUAL SOILS			
74.	Union stony loam	2,432	0.7

TABLE IV. PLANT FOOD IN LEE COUNTY SOILS, IOWA. (SURFACE), POUNDS PER ACRE OF TWO MILLION POUNDS OF SURFACE SOIL (0-6- $\frac{2}{3}$ ")

Soil No.	Soil type	Total phos-phorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Lime-stone requirement
LOESS SOILS						
64.	Grundy silt loam	1092	3300	43,183	136	5822
65.	Lindley loam	580	1330	14,692	Trace	2569
66.	Putnam silt loam	1112	3540	41,244	Trace	6239
31.	Memphis silt loam	1074	1830	20,189	146	4037
67.	Marion silt loam	850	2490	37,140	160	3253
68.	Grundy clay loam	1456	5380	50,166	Trace	1835
TERRACE SOILS						
36.	Buckner silt loam	1160	1820	29,124	176	7707
69.	Buckner very fine sandy loam	700	2480	28,240	320	4037
45.	Buckner fine sandy loam	840	800	5,700	0	2469
46.	Buckner fine sand	940	920	8,220	0	4037
38.	Buckner loam	1640	2460	28,180	0	6139
SWAMP AND BOTTOMLAND SOILS						
70.	Genesee very fine sandy loam	740	1060	14,720	0	Basic
71.	Genesee silt loam	1062	4400	50,508	112	Basic
26.	Wabash silt loam	1796	4920	54,584	Trace	4771
26a.	Wabash silt loam (Colluvial phase)	1074	3900	50,166	Trace	6973
72.	Wabash clay	1606	4520	48,826	Trace	4037
48.	Wabash silty clay loam	1804	3540	43,108	112	4037
62.	Wabash fine sandy loam	1688	2300	27,668	112	8441
49.	Wabash loam	1392	2960	39,184	Trace	6973

determinations were always made and in the case of the major soil types, where several samples were analyzed the figures are the average of duplicate determinations on *all* the samples of the type analyzed. These figures are all given on the basis of pounds per acre of two million pounds of surface soil.

According to these results there is no large amount of phosphorus present in any of the soils in the county. With the exception of one of the terrace soils, all the upland soils contain less than 1500 pounds per acre. The Lindley loam and the Marion silt loam are low in phosphorus as are three of the terrace soils. The swamp and bottomland soils are somewhat higher in phosphorus than the other groups of soils, but in no case is there any considerable amount present. It is interesting to note that in all the soil groups, the darker colored soils are very much better supplied with phosphorus than are the light colored types. The heavier types of soil are slightly better supplied with phosphorus than the sandy soils. There seems to be a greater variation in phosphorus content among the individual soil types than among the various soil groups. The phosphorus content of the soils of Lee county, altho always rather low, is somewhat variable depending on the color and type of soil and on its location and topography. It is very generally needed on the soils of the county in order to keep them permanently fertile as is very clearly shown by these data.

Altho the amounts of nitrogen present are generally much greater than is the case with phosphorus, the soils of the county are not particularly high in this element. The loess soils with two exceptions are fairly well supplied but the nitrogen content of the terrace soils is low. The swamp and bottomland soils average somewhat higher than the other groups of soils, but the differences are not large. As in the case of the phosphorus the soils which are darker in color are higher in nitrogen. Nitrogen in soils is mainly in the organic matter and a dark colored soil would naturally be richer in nitrogen than one of a lighter color.

The variations in the carbon content in the different soil types are very similar to the variations in the nitrogen content. The carbon and nitrogen in soils are always very closely related because these two elements make up the organic matter. The amounts of organic carbon like the nitrogen are higher in the swamp and bottomland soils. The terrace soils are low and so also are two of the loess soils. The other loess soils altho better supplied contain less on the average than the lowland soils. There is a greater difference in both nitrogen and carbon between the individual types than between the various groups of soils. The color and physical character of the soil give a very good indication of the content of organic matter and of carbon and nitrogen. In some soil types the relation between the nitrogen and the carbon is such that bacterial activities are not at the best and hence decomposition processes are not occurring with sufficient rapidity to keep the crops supplied with available plant food. In such cases manure should be applied. With the sandy terrace soils, manure would be of double value in adding nitrogen and carbon in which the soils are lacking and also in increasing the decomposition processes. With one exception in most of the upland and bottomland soils, the relation between nitrogen and carbon is satisfactory. The Grundy clay loam, a loess soil, altho high in total content of organic matter, is very much in need of the addition of manure to put it in the best condition for crop growth.

On the soils of this county which are low in organic matter and nitrogen, farm manure, leguminous green manures and crop residues should be used. Even tho all the soils are not actually deficient in these constituents, they will be benefited by the rational use of the materials mentioned and for their permanent fertility such substances are absolutely essential.

Except for two bottomland soils which are basic in reaction all the soils in Lee county are rather high in limestone requirement. There is apparently no relation between the requirements of the soils in the various groups. In fact, there is more variation in the acidity of the types within each group, than between the soils in the various groups. The lime requirement of a soil is an extremely variable factor and the figures given are merely indicative of the needs of the different soil types. Other samples of the same types would undoubtedly show variations in acidity and broad conclusions should not be drawn from the figures given. In general, however, the soils of Lee county are in immediate need of lime to remedy acidity and in some cases this need may be for a rather considerable amount. The upland and terrace soils, are all acid in reaction as are most of the bottomland soils. Even those two types which show no acidity have no large content of lime and they too will soon be in need of it. The absence of any considerable amount of inorganic carbon in any of the soils is a noticeable feature of the analyses and indicates that the soils are acid in reaction or will soon become so.

The amounts of lime to apply to any soil should not be determined from average figures, even tho they are secured from a large number of analyses. Actual tests of individual soils should be made to ascertain the amount of lime needed in each particular case. In that way the use of enough lime can be guaranteed and an excessive application can be avoided.

All the soils of Lee county should be tested for acidity at regular intervals and lime applied as necessary if the best crop yields especially of legumes are to be secured and the soils are to be kept fertile.

THE SUBSURFACE SOILS AND SUBSOILS

The subsurface soils and subsoils corresponding to the surface soils already discussed were analyzed for the same constituents. The results of these analyses are given in tables V and VI, the figures being calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil. The amounts of plant food present in the lower soil layers in Lee county are apparently not large enough to materially affect the needs of the surface soils. If the surface soil is low in any constituent the only effect of a small amount of that element in the subsoil is to delay somewhat the time when crops will be in need of that particular plant food. The actual content of plant food in the lower soil layers is of much less significance than that in the surface soil.

The percentage contents of nitrogen, phosphorus and carbon are lower in the subsurface soils and subsoils of Lee county than in the surface soils. Hence a lack of these constituents in the surface soils must be remedied by proper additions of fertilizing materials, if satisfactory crop yields are to be secured. The needs of the soils of the county for manure, to keep up the organic matter and nitrogen content, for green manure crops as a supplementary treatment and for the addition of phosphorus fertilizers are shown also

TABLE V. PLANT FOOD IN LEE COUNTY SOILS, IOWA, (SUBSURFACE), POUNDS PER ACRE OF FOUR MILLION POUNDS OF SUBSURFACE SOIL (6- $\frac{2}{3}$ "-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Lime-stone requirement
LOESS SOILS						
64.	Grundy silt loam	1645	3826	38,442	170	5873
65.	Lindley loam	796	1320	19,732	188	8441
66.	Putnam silt loam	1462	3560	43,046	114	8608
31.	Memphis silt loam	2020	1960	25,978	282	4304
67.	Marion silt loam	1300	2340	23,278	142	6606
68.	Grundy clay loam	1912	5520	78,452	148	Basic
TERRACE SOILS						
36.	Buckner silt loam	2360	3240	18,476	566	13,946
69.	Buckner very fine sandy loam	1680	3120	50,640	0	6606
45.	Buckner fine sandy loam	1760	1400	6,480	0	4938
46.	Buckner fine sand	1720	1840	18,916	924	6606
38.	Buckner loam	2040	4400	39,120	1208	7340
SWAMP AND BOTTOMLAND SOILS						
70.	Genesee very fine sandy loam	1360	2960	15,720	0	Basic
71.	Genesee silt loam	1784	4480	36,492	148	Basic
26.	Wabash silt loam	1880	3720	46,168	152	8074
26a.	Wabash silt loam (Colluvial phase)	1944	6760	92,212	148	13,946
72.	Wabash clay	2148	4960	53,772	148	3670
48.	Wabash silty clay loam	2640	4240	36,812	148	3670
62.	Wabash fine sandy loam	2680	3480	43,932	148	6606
49.	Wabash loam	2392	4960	35,128	152	9542

TABLE VI. PLANT FOOD IN LEE COUNTY SOILS, IOWA, (SUBSOIL), POUNDS PER ACRE OF SIX MILLION POUNDS OF SUBSOIL (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Lime-stone requirement
LOESS SOILS						
64.	Grundy silt loam	2034	2960	39,990	450	8808
65.	Lindley loam	1293	2070	31,848	282	19,267
66.	Putnam silt loam	2292	3810	40,698	168	11,412
31.	Memphis silt loam	3255	2130	19,695	225	11,560
67.	Marion silt loam	2730	3150	17,910	0	12,111
68.	Grundy clay loam	2568	3480	41,100	564	Basic
TERRACE SOILS						
36.	Buckner silt loam	2340	2640	19,260	0	18,417
69.	Buckner very fine sandy loam	2280	4020	40,920	0	9909
45.	Buckner fine sandy loam	2160	1980	10,800	0	3303
46.	Buckner fine sand	2220	2820	14,100	0	7407
38.	Buckner loam	2880	4860	40,080	0	6606
SWAMP AND BOTTOMLAND SOILS						
70.	Genesee very fine sandy loam	1440	2940	15,774	1866	Basic
71.	Genesee silt loam	1764	3660	39,066	114	Basic
26.	Wabash silt loam	3732	2640	28,926	114	9909
26a.	Wabash silt loam (Colluvial phase)	1830	4740	76,386	114	13,212
72.	Wabash clay	2976	5220	65,718	222	5505
48.	Wabash silty clay loam	3450	4320	42,216	444	4404
62.	Wabash fine sandy loam	2760	2100	28,206	114	6606
49.	Wabash loam	3420	4380	46,266	114	9909

TABLE VII. GREENHOUSE EXPERIMENT GRUNDY SILT LOAM

Treatment	Yield Gms.
1. Check	5.7
2. Lime	7.5
3. Lime and manure	16.5
4. Lime and rock phosphate	9.0
5. Lime and acid phosphate	10.5
6. Lime and manure and rock phosphate	15.0
7. Lime and manure and acid phosphate	14.7

by the analyses of the subsurface soils and subsoils. The acidity of the lower soil layers is greater than that at the surface and makes very evident the general need of lime on these soils. Enough lime should be used to neutralize the acidity in the surface soil, but it is not necessary or advisable to make large enough applications to remedy the acidity in the subsoil.

GREENHOUSE EXPERIMENTS

Greenhouse experiments were carried out on two of the chief soil types in Lee county, the Grundy silt loam and the Memphis silt loam. The Grundy silt loam used in the test was taken from Van Buren county but the same type occurs in Lee county and the results secured are undoubtedly directly applicable to the same type in both counties.

Both the Grundy and the Memphis are loess soils and cover a considerable area in the county.

The first experiment consisted in the treatment of the soil with lime, manure, rock phosphate and acid phosphate according to the plan shown in table VII. Enough lime was applied to neutralize the acidity of the soil and two tons additional were used to put the soil in the best reaction for crop growth. Manure was added at the rate of 10 tons per acre, rock phosphate at the rate of 1000 pounds per acre and acid phosphate at the rate of 200 pounds per acre. The pots were seeded to Marquis spring wheat and kept as near optimum conditions of temperature and moisture as was possible under greenhouse conditions. When the crop was matured, it was harvested and the yield of grain obtained. The average results for the duplicate pots are given in the table.

According to these results lime brot about some small increase in crop



Fig. 2. Greenhouse experiment with Grundy silt loam. The mature wheat growing in these pots shows the relative effect of various treatments of Lee county soil. Manure used with lime brought about the greatest increase.

TABLE VIII. GREENHOUSE EXPERIMENT MEMPHIS SILT LOAM

Treatment	Yield Gms.
1. Check	7.50
2. Lime	6.75
3. Lime and manure	11.75
4. Lime and manure and rock phosphate	11.75
5. Lime and manure and acid phosphate	11.75

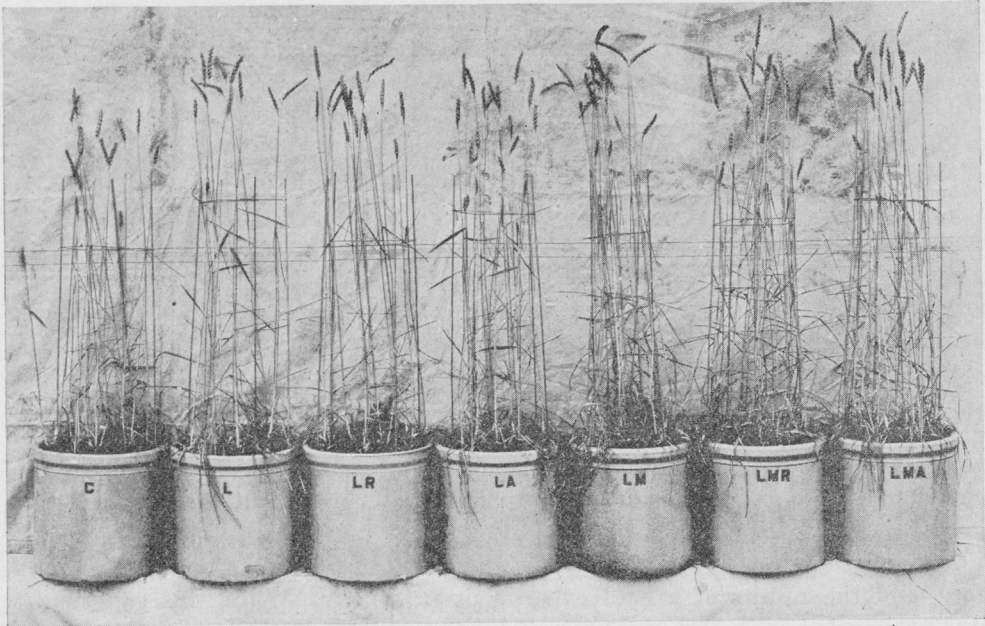
growth. When rock phosphate or acid phosphate was applied with the lime somewhat greater results were secured, the acid phosphate showing up slightly better than the rock. Manure used with the lime showed an increase in crop yield over twice as large as in the case of the lime alone, and very much larger than the yield obtained with the lime and phosphorus fertilizers. When acid phosphate or rock phosphate was applied with the lime and manure no increase was secured over the treatment with these latter materials alone. The yields which are almost identical for the two phosphorus fertilizers, are actually slightly lower than that given by the lime and manure. The difference, however, is not great and merely justifies the conclusion that the phosphorus fertilizers have not increased the yields.

These results indicate that the application of lime is of some value on this soil and that manure used with the lime is of greater importance than other fertilizing materials in increasing the crop yield. The use of the phosphorus fertilizers in addition to manure was not profitable. Manure is evidently the best fertilizing material for this soil type *now* but phosphorus fertilizers will also be needed in the future.

In the second greenhouse experiment on the Memphis silt loam the soil was treated with lime, manure, rock phosphate and acid phosphate, just as in the preceding experiment. Sufficient lime was used to neutralize the acidity of the soil and two tons additional were added to bring the soil up to a desirable reaction for crop growth. The other fertilizing materials were added as in the other experiment, the pots were seeded and treated as usual and the yield of wheat secured as before. The results of this experiment are shown in table VIII, the average yields of wheat being given in grams.

Lime did not bring about any noticeable increase in the yield of wheat with this soil. This does not necessarily mean that this particular soil should not be limed, inasmuch as wheat, the crop grown, does not always respond to applications of lime unless the soil is strongly acid. This soil type is usually acid and general experience indicates that lime is necessary for the best growth of many crops, especially clover and alfalfa. All soils should be tested for acidity and when acid, lime should be applied in the proper amounts. The effects of applications of lime are most pronounced on the legume which is used in the rotation and lime is especially essential for use prior to the growth of that crop.

Manure used with the lime resulted in a very large increase in crop yield but when rock phosphate or acid phosphate was used with the manure the crop was not affected. These results indicate that manure is the best fertilizing material for this soil at the present time and that the resultant crop increases well warrant its application. Other fertilizing materials when applied in addition to the manure are apparently of little use now but phosphorus will certainly be needed on this soil in the future.



No. 3. Greenhouse experiment with Memphis silt loam. As in the previous experiment manure used with lime resulted in the largest increase in crop yield.

FIELD EXPERIMENT WITH GUMBO

Within the state there are areas of soil popularly called "gumbo" which have received special attention for several years because of the difficulty in farming them and because of their need for special treatment.

The term "gumbo" is not a recognized name for a particular class of soils, according to any accepted scheme of soil classification. It is a popular name for a group of soils which possess characteristics well known and dreaded by farmers. It is very different from the gumbo referred to in geological reports which includes almost impervious gray or yellow clay subsurface soils.

The soil that Iowa farmers call "gumbo" is a heavy, "greasy" black clay soil, occurring in flat areas, either river bottoms or level uplands. It is usually inky black and is stickier and bakes more easily than any other type of soil in the state. If such soil is plowed when too wet it balls up before the plow point in such a way that the implement cannot be made to stay in the ground. On the other hand, if it becomes too dry it will turn up in clods which cannot be worked down during the whole season. Where such clods are formed, freezing and thawing is the only process which will restore the loose, mealy structure. This soil can, however, be put in excellent tilth, with a fine, mealy appearance and kept so during the entire season provided it is not cultivated when too wet.

The total area of "gumbo" in Iowa is probably about one percent of the entire state, occurring in small patches in various localities. The principal areas are in southeastern Iowa and along the Missouri river in western Iowa. The counties in which "gumbo" has been found are Muscatine, Washington, Louisa, Henry, Des Moines, Van Buren, Lee, Woodbury, Monona, Harrison and Pottawattamie.

Lee county contains an upland loess soil known as the Grundy clay loam,

TABLE IX. FIELD EXPERIMENTS ON "GUMBO"

Plot. No.	Treatment	Bu. corn per acre 1909
<i>Drained</i>		
101	Rape (too wet)	24
102	Buckwheat	62
103	Clover	94
104	Check	77
105	Lime — 10 T per acre	68
106	Straw — 4 T per acre	47
107	Check	40
108	Manure — 12 T per acre (too wet)	23
109	Manure — 6 T per acre (too wet)	14
<i>Undrained</i>		
201	Clover and timothy sod	7
202	Clover and timothy sod	10
203	Manure — 12 T per acre	15
204	Check	27
205	Manure — spring plowed	20
206	Check — spring plowed	20

which is a typical "gumbo". This type covers 0.5 percent of the area of the county and occurs in flat depressions scattered throughout the Grundy silt loam, the main loess soil.

The management of "gumbo" may profitably be considered at this point, therefore, and the results of a field experiment presented. While this experiment was not carried on in this county, it yielded results applicable to "gumbo" soils everywhere in the state.

This experiment was located on a typical area of "gumbo" bottomland near Wapello, Louisa county. Two series of plots were laid out in 1908, one consisting of six plots which were undrained and one of ten which were as well drained as conditions would permit. The treatment and yields of corn in 1909 are given in table IX.

Plots 101, 102, 103, 201 and 202 were green manured in 1908 with rape, buckwheat, clover and clover and timothy, respectively. The clover and timothy on plots 201 and 202 had been a meadow for several years and produced a crop of hay in 1908 which made a yield of $21\frac{1}{2}$ tons per acre. The aftermath was plowed under for green manure. All, except plots 205 and 206, were fall plowed in 1908, the treatments indicated being made prior to plowing.

In the fall plowing it was noticed that the clover and buckwheat plots worked much more easily than the others. The following season the plots which received manure dried out more slowly after a wet spell than the others. Further observations on the effects of treatment could not be made.

Great differences in yield occurred but these should undoubtedly be attributed to differences in drainage rather than to the effects of treatment. It was impossible to get a satisfactory outlet for the tile drain and on each side of the experiment field there was a swampy place in which the water stood nearly all summer and this surely affected the results from the outside plots. (101, 108, 109).

Where the soil was fall plowed, a fine mealy seed bed was obtained for the corn which was planted on May 13. Surrounding undrained land which was not fall plowed could not be planted until about June 10. The undrained plots were too wet nearly all summer and the outside plots in the drained series were also too wet. In the latter part of the summer all of the plots dried out well at the surface and the undrained ones cracked open, leaving wide fissures to a

depth of more than a foot. On the best drained plots, the fine crumbly surface soil prevented this cracking. On the hard, cracked ground the corn turned yellow and "fired" about the middle of August, but on the other plots it remained green at least three weeks longer.

The fall plowed plots were fairly clean of weeds and grass while the others were very foul. The lime treatment of plot 105 seemed to have no effect on the "gumbo."

This experiment shows very definitely the possibilities of "gumbo" soils when properly drained and fall plowed. The drainage of "gumbo" is more readily accomplished than would be supposed. On the upland the tile should be laid 8 rods apart to secure good drainage, altho reports have been made of successfully drained "gumbo" when the tile was 10 to 12 rods apart. On the lowland "gumbo" the tile should be somewhat closer together, but the securing of a satisfactory outlet is the chief necessity for thoro drainage and in some cases it may be necessary to run an open ditch thru to the river, in which case a drainage district must be organized. When properly tiled out such "gumbo" soil is equal to any other soil in the state in producing power for general farm crops. Fall plowing improves the soil very decidedly and the use of clover or some other green manure is also of value.

The occurrence of "gumbo" on farm need not be a cause of lower value of the farm. It may be made and kept productive thru the treatments mentioned above and is then equal in value to the best farm land.

THE NEEDS OF LEE COUNTY SOILS AS SHOWN BY THE LABORATORY AND GREENHOUSE TESTS

Altho no field tests on the soils in Lee county are yet available, work is now underway which it is hoped will, in a few years, permit of definite conclusions regarding the value of the use of various fertilizing materials. Data secured in these field tests will be presented later in a supplementary report.

For the present the needs of the soils can be determined, only from the laboratory and greenhouse studies but rather definite conclusions are drawn based not only on the data at hand but also on the results of experiences of many farmers and on observations made thruout the county.

LIMING

One of the first needs of the soils of Lee county to make them properly productive is the use of lime. All of the upland soils which were tested were decidedly acid in reaction as were also most of the bottomland soils. The subsurface soils and subsoils were generally acid and even when they were basic the amount of lime present was so small as not materially to affect the need of lime by the surface soil. Lime moves upward in the soil only in very small amounts and there is such a rapid loss in the drainage water that an acid condition in the surface soil is not remedied by a high lime content in the lower soil layers.

General field experience shows very definitely that lime is of value on many soils in Lee county, causing large increases in the growth of crops especially in the case of legumes such as clover and alfalfa. All the soils of the county should be tested for their reaction and if they are found to be acid lime should



Fig. 4. Grundy silt loam topography in Lee county

be applied. The analyses if properly made will also show the amount of lime which is required to put a particular soil in the best condition for crop growth. Thus an excessive amount will not be applied nor will an insufficient application be made. Farmers may send samples of their soils to the Soils Section of the Iowa Agricultural Experiment Station and have them tested, free of charge, and will thus be assured that they are adding the exact amount of lime needed by their soils.

The effects of lime on various crops, the methods and time of application and other problems connected with liming acid soils are considered in another bulletin.¹ Suffice it to say here that lime can be secured quite cheaply and the returns obtained, especially in the case of legumes, much more than warrant the cost and labor involved in its use.

MANURING

The need of organic matter on many of the soils in Lee county has already been noted. It was found that several of the upland and terrace soils, particularly those light in color and sandy in texture were quite low in organic matter. The bottomland soils were better supplied but even in the case of some of those soils it was found that the decomposition processes brought about by bacterial activities were not proceeding properly and the use of farm manure would be valuable.

The unsatisfactory crop growth secured in many cases on the Lindley loam, the Putnam silt loam, the Memphis silt loam and especially the Marion silt loam is very largely the result of a lack of organic matter. Some of the terrace soils are not satisfactorily productive for the same reason.

The greenhouse experiments show very decided benefits from the use of manure on the Grundy silt loam and the Memphis silt loam and farm experience on the other upland soil types of the county proves beyond question that farm manure is the most valuable fertilizing material which can be used at the present time.

Farm manure is too often regarded as a waste product on the farm and is

not properly cared for nor applied to the soils so as to accomplish the best results. The losses which farm manure undergoes if improperly stored may be very large and may considerably reduce the value of the material. If it is piled loosely and unprotected from the weather and the soluble portion is allowed to wash away, the loss of plant food may amount to as much as 85 percent of that originally present. Farm manure returns to the soil a portion of the plant food removed by crops which are fed on the farm and the application of such material may be of much importance in keeping up the fertility of the soil, provided its value is not lost thru improper storing. The methods which should be followed to protect manure from losses are dealt with in another publication.¹ In general it may be said that manure should be kept compact and moist and protected from the weather if the greatest value is to be secured from its use.

It is not merely as a carrier of plant food that manure is of value. The organic matter which it adds to the soil is of great importance in improving the physical conditions both of heavy and light soils. It also adds numerous bacteria which bring about decomposition processes and thus increase the production of available plant food.

Farm manure should be applied in as large amounts as practicable to Lee county soils if their fertility is to be increased. The production of manure on the average farm is not so large that there is danger of applying too much. Larger application than 16 to 20 tons per acre are not advisable nor economical, however, except when truck crops are to be grown, in which case the amounts which can be used with profit may be much greater.

In many cases on livestock farms and quite generally on grain farms the production of manure is not great enough to permit of even a normal application of 8 to 10 tons per acre once in a rotation on all the soils of the farm. In such cases green manures should be used to supplement the farm manure as a means of keeping up the content of organic matter in the soil. Various crops may be grown and turned under as green manures but the legumes are by far the most desirable. Properly inoculated legumes are able to use the nitrogen of the atmosphere and, therefore, when turned in the soil they not only give all the beneficial effects from the addition of organic matter but they also *add nitrogen to the soil*. There are numerous legumes which may be used as green manures and the one chosen should be adapted to the soil and climatic conditions. With proper inoculation and growth, the increase in the fertility of the soil may more than offset the expense involved. Green manuring is necessary on grain farms where farm manure is not produced and it may also be practiced to advantage along with manuring on many livestock farms.

It is not necessary to consider the relative merits of green manuring and the use of farm manure for from the practical standpoint all the latter material produced on the farm should always be used and green manuring employed as a supplementary means of keeping up the organic matter content of the soil.

Another means of maintaining the organic matter in the soil is by the proper return of all the crop residues, such as straw and stover. These materials should never be wasted, for they not only contain some of the plant food removed from the soil by the crop but they also supply much valuable organic matter. In

¹ Cir. 10, Ia. Agr. Expt. Sta.

grain farming it is particularly important that the crop residues all be returned to the soil, but in livestock farming also these materials are valuable when applied to the soil along with the farm manure and they should not be burned or otherwise destroyed.

THE USE OF COMMERCIAL FERTILIZERS

Attention has been called to the fact that Lee county soils are not rich in phosphorus. In fact, some of the upland and terrace soils are quite low in that element and it might seem that the use of phosphorus fertilizers would be distinctly valuable on these soils.

The greenhouse experiments on the Grundy silt loam and the Memphis silt loam did not show profitable effect from the use of either rock phosphate or of acid phosphate. These soils were not as low in phosphorus as some of the others and it might be that different results would have been secured with other soils. Therefore, it should not be concluded from these data that phosphorus fertilizers should not be used on any Lee county soils. It is quite probable that in certain cases the productivity of the soil might be economically increased by the use of phosphorus. The field tests which are now under way in the county are planned especially to test the need of phosphorus but the results of these tests will not be available for several years and in the meantime farmers are urged to make tests on their own soils. Specific directions for the carrying out of such tests are given in Circular 51 of the Iowa Agricultural Experiment Station and the Soil Section will be glad to advise farmers who are interested in determining the needs of their soils.

It cannot be stated that phosphorus should be used on any particular soils now, but it can be definitely said that the soils are low in that element and in the future the addition of phosphorus fertilizers will undoubtedly be necessary. Furthermore on some soils, applications might prove profitable even now.

When the need of phosphorus is evidenced on a soil the first question is which kind of phosphorus fertilizer should be used. Rock phosphate and acid phosphate are the two principal materials now on the market and as there is a difference in composition and cost, there is probably also a difference in the value of results from their use. Rock phosphate carries the phosphorus in an unavailable form but it is cheaper than the acid phosphate in which the phosphorus is readily available. The field tests now under way include the use of both these materials and it is hoped that in a few years definite data will be available to show which material should be applied to certain soils. For the present a choice between the two fertilizers cannot be recommended and farmers who are interested are urged to test both materials on their own soils. More definite knowledge can be secured by individuals in this way than by general experiments owing to the variations in need which are shown not only between different soil types but also between soils of the same type occurring in different locations and modified by various methods of management.

No analyses were made of the soils of Lee county for potassium as all the soils of the state have been found to be well supplied with that element. Potassium fertilizers are not believed to be necessary on Iowa soils for the satisfactory

production of general farm crops as with proper physical conditions in the soil and abundant organic matter the potassium present should be changed into an available form sufficiently rapidly to keep the crops supplied.

Nitrogenous fertilizers also do not seem to be necessary in Lee county. The soils are not rich in this constituent, but by the use of well-inoculated legumes nitrogen may be added to the soil from the atmosphere. The use of leguminous green manures may serve as a cheap means of maintaining nitrogen in the soils and except for truck crops or in small applications to stimulate initial crop growth, nitrogenous fertilizers would probably not prove economically valuable.

Complete commercial fertilizers are probably not generally needed on the soils of the county. Field tests are now under way with these materials. If they prove profitable they may be used without fear of injury to the land. Complete fertilizers especially adapted to certain truck crops may often be used to advantage but definite suggestions along this line cannot be given here. Truck crop farmers may secure advice along this line from the Truck Crops Section of the Iowa Agricultural Experiment Station.

DRAINAGE

Altho most of the soils in Lee county are well drained, there are some areas which will be benefited by the use of tile. The Marion silt loam, the Putnam silt loam, the Grundy silty clay loam, the Buckner silt loam, the Wabash silty clay loam and the Wabash clay are all in need of drainage. This need is the most pronounced in the case of the Grundy clay loam locally known as "gumbo" but the proper installation of tile drains would prove distinctly valuable in many cases on the other types. If a soil is improperly drained, crop production will not be satisfactory and all other methods of soil treatment will be practically valueless if drainage is poor. It is not advisable to apply lime, manure, or phosphorus to poorly drained soil. Adequate drainage is the first treatment necessary to increase the productivity of wet soils. The cost of tiling may be considerable but the expense involved is well warranted by the beneficial effects brot about on crop production.

CROP ROTATIONS

Tests on many soils under a wide variety of conditions have shown that the rotation of crops is always necessary if soils are to be kept fertile. All rotations should contain a regular legume crop and especially on grain farms one or more legume "catch" crops may be used with profit. If Lee county soils are to be kept productive, therefore, a proper rotation of crops must be followed. No particular rotation can be recommended as especially desirable in the county because of variations in the systems of farming, capital, size of farm and other factors. The following rotations may, however, be suggested:

1. FOUR OR FIVE YEAR ROTATION

First year, corn with cowpeas, rape or rye seeded in the standing corn at the last cultivation).

Second year, corn.

Third year, oats with clover or with clover and timothy.

Fourth year, clover. (If timothy was seeded with clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.

2. FOUR YEAR ROTATION WITH ALFALFA

First year, corn.

Second year, oats.

Third year, clover.

Fourth year, wheat.

Fifth year, alfalfa. (This crop may remain on the land five years. This field should then be used for the four year rotation outlined above.)

3. THREE YEAR ROTATION

First year, corn.

Second year, oats or wheat. With clover seeded in the grain.

Third year, clover. Only the grain and clover seed should be sold; in grain farming, most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land.

In live-stock farming, the products grown in the rotation should, for the most part, be fed or used for bedding, and the manure carefully saved and used as a fertilizer.

"Catch" crops, such as cowpeas, soybeans, vetch and clover, seeded in standing corn are frequently unprofitable in Iowa because of the high cost of the seed and the failure of the crop to make a satisfactory growth. The non-legumes, such as rye and rape usually do well when seeded in standing corn.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action. The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manures, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By

all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Lee county, there are some areas where gullying occurs to an injurious extent. The bluffs extending from the upland to the alluvial bottoms are often very badly dissected as a result of erosion. The Lindley loam, the Memphis silt loam and the Union stony loam are especially subject to washing because of the steep slopes on which they occur.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

"Plowing In."—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In."—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three to four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land.

Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

"Staking in."—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving in time, labor and inspection.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass. Considering the cost, maintenance, permanence, and efficiency, the Christopher or Dickey

dam, especially when arranged in series of two or more, may be regarded as the best method of filling ditches and gullies and as especially adapted to the larger gullies.

The stone or rubble dam.—Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when the openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The rubbish dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The woven wire dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for preventing erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod strips.—The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. The method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The concrete dam.—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage.—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher dam, already described, may also serve in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and tiling.—The straightening of the larger streams in bottom land areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottom land and it often proves very efficient.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of organic matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw, corn stalks, etc., may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing of crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite necessary for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

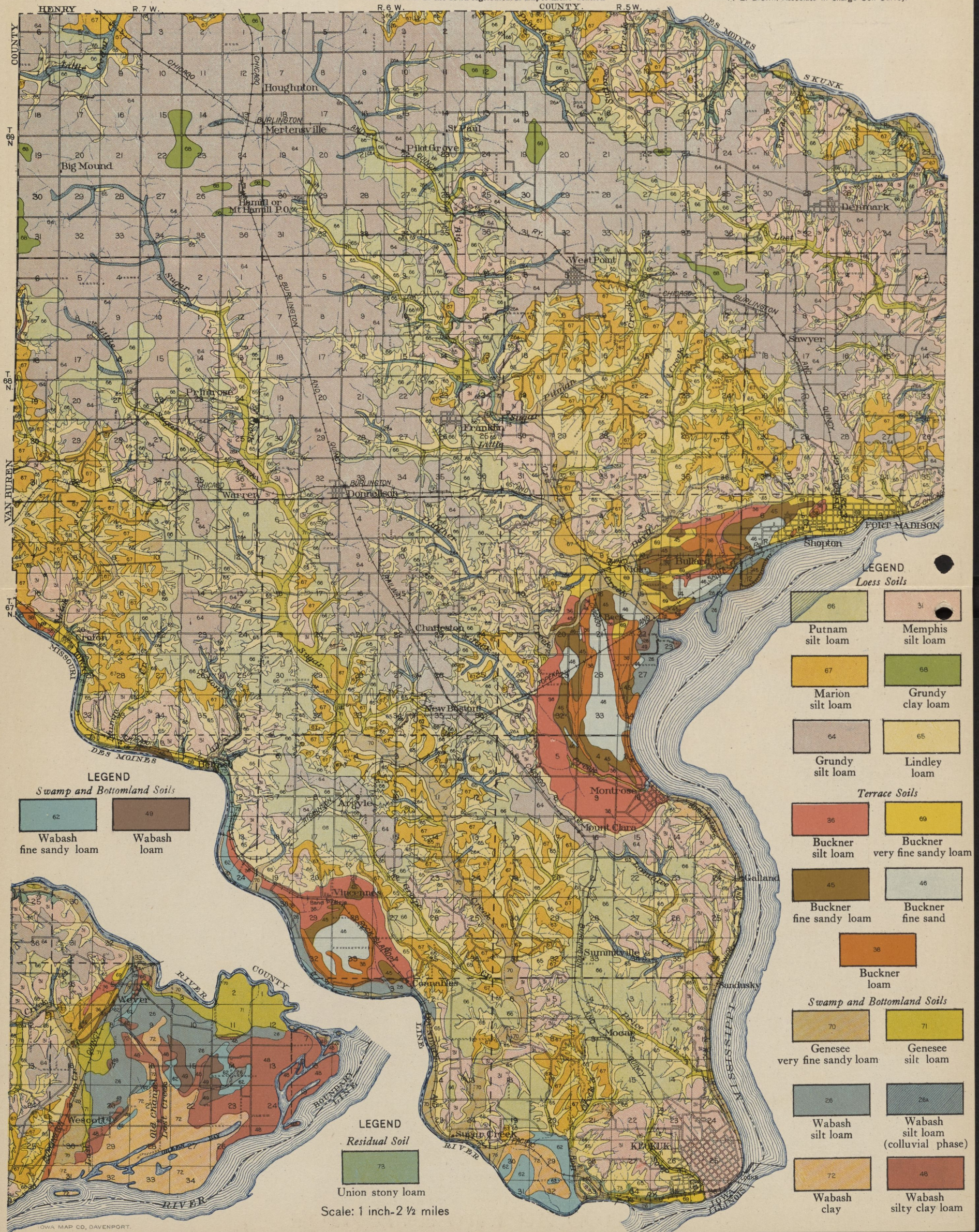
Contour discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This prac-

SOIL MAP OF LEE COUNTY

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut, in charge Soil Survey.

W. E. McLendon, Inspector Northern Division.
Soils surveyed by L. V. Davis of the U. S. Department of Agriculture,
and M. E. Sar of the Iowa Agricultural Experiment Station

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director. W. H. Stevenson, in charge Soil Survey.
F. E. Brown, Associate in charge Soil Survey.



tice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Deep plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN LEE COUNTY

LOESS SOILS

There are six loess soils in Lee county including the Grundy, Lindley, Putnam, Memphis and Marion series. These soils cover nearly 80 percent of the total area of the county and are the most important types.

GRUNDY SILT LOAM (64)

This soil occurs on the rather level uplands and is the prevailing type in the northwestern part of the county. It covers the largest area of any type mapped and is the most important soil in the county.

The surface soil to a depth of 12 to 14 inches is a dark brown to black silt loam. This is underlain by a dark-brown to black silty clay loam which at a depth of about 24 inches grades into a clay loam mottled with pale yellow, yellowish-brown and bluish-gray. In the deeper subsoil the material becomes heavier in texture and approaches a silty clay. In the level areas the subsoil is a dark-brown to bluish-gray in color with little yellow or yellowish-brown and a heavier texture. In topography this soil is rolling to level. The drainage is usually good except in the level areas where the use of tile would be of value.

The crops grown successfully on the Grundy silt loam are corn, oats, rye, wheat, clover, timothy, and alfalfa. It is the best soil in the county for corn and oats and high average yields are secured for both these crops. Spring wheat and winter wheat yield well as do also timothy and clover. Alfalfa has been grown very successfully in recent years and its production is increasing.

Altho crop yields are good on the Grundy silt loam, proper methods of treatment will bring about profitable increases. The soil is generally acid in reaction and it should be tested at frequent intervals to determine its need for lime. With the applications of lime the yields especially of the legume crops will be greatly increased. Farm manure has been found distinctly valuable on this soil both in the greenhouse tests and in farm experience. Notwithstand-

¹ The descriptions of individual soil types given in the Bureau of Soils report have been rather closely followed in this section of the report.

ing the presence, according to the chemical analyses, of considerable organic matter in the soil the use of farm manure and in many cases also the turning under of green manures would be profitable. These materials are not only of value in bringing about present increases in fertility but they are absolutely necessary if the soil is to be kept permanently fertile.

Phosphorus is not abundant in the Grundy silt loam but the greenhouse experiment did not show profitable increases from the application of either rock phosphate or acid phosphate. In the future, the use of phosphorus fertilizers will undoubtedly be necessary and in some cases it might prove profitable even now. The field experiments which are now under way and which will be reported later will throw some interesting light on this problem. They will also show the relative merits of rock phosphate and acid phosphate. For the present phosphorus fertilizers should not be used until tests have been made on the farms and their value ascertained.

LINDLEY LOAM (65)

This soil type occurs to a large extent thruout Lee county, being second in area to the Grundy silt loam. It occupies the slopes leading to upland drainage courses, and is well drained.

The surface soil extending to a depth of about 10 inches is a reddish to yellowish-brown loam to silt loam. On the tops of the slopes the soil approaches a silt loam while on the slopes themselves it is more loamy in texture. The subsoil material is a reddish to yellowish-brown clay loam to silty clay or sandy clay. Pockets of sand and clay frequently occur in the lower soil layers. Fragments of various rock materials are found scattered thruout the surface soil as well as the subsoil and some large boulders also occur.

The slopes on which this soil occurs are sometimes rather steep and in such cases the land is not suited for cultivation. Probably only one-fourth to one-third of the total area of the type in the county is being cultivated. There are some uncleared areas where a growth of scrub oak, white oak, red oak and black and shellbark hickory is supported.

On the more level portions of the soil, oats, rye and grass do well but corn does not produce as good crops as on the darker soils. Alfalfa gives satisfactory yields in some cases, but it is not grown to any large extent. Where such crops cannot be grown bluegrass makes an excellent pasture.

The Lindley loam is fairly productive but the yields of cultivated crops can be increased considerably thru proper soil treatment. The soil is acid in most cases and should receive applications of lime to put it in the best condition for the growth of crops, particularly the legumes. It is not well supplied with organic matter and applications of farm manure prove distinctly profitable. If farm manure is not available in any considerable amount, green manures should be used to build up the soil. Phosphorus is low and the application of phosphorus fertilizers might prove profitable at the present time and certainly will be necessary in the future. With the proper use of these materials that portion of the Lindley loam which is not too steep for cultivation can be made and kept much more productive than is the case at present. The steeper portion of the soil can be very profitably utilized for pasture and proper methods should be followed to improve old pastures and keep them in good condition.

The cultivated portion of the soil is subject to erosion and care should be exercised to prevent the injurious washing away of the surface soil.

PUTNAM SILT LOAM (66)

This soil occurs thruout the uplands of the county, generally around the drainage courses. It separates the Grundy silt loam from the Lindley loam on the slopes or from the Marion or Memphis silt loam on the narrow divides occupying level areas in the northwestern part of the county while in other places the topography is gently sloping. The surface drainage is good but the underdrainage is poor and the soil is frequently in need of tiling.

The surface soil consists of a dark-brown or grayish-brown to black silt loam extending to a depth of 8 to 14 inches. From this point to a depth of 20 or 22 inches there is a dark-gray silty clay loam. This layer in some places is light-gray in color. At 20 or 22 inches the soil changes abruptly to a clay loam to silty clay, dark-brown in color and mottled with yellowish-brown, rusty brown and bluish-gray. In the more level areas, the subsoil is heavier in texture and the color is darker.

This soil is similar to the Grundy silt loam in crop adaptation but it is not quite as productive. It is not as good a corn soil and it does not withstand drouth as well. Oats, spring wheat, winter wheat, rye, timothy and clover are the crops grown in addition to corn and in favorable seasons fairly good yields of these crops are secured.

The need of drainage due to the heavy subsurface layer is frequently evident and the laying of tile would in many cases prove of much value. Lime is generally needed as the reaction of the soil is acid. While the organic matter content is not so low as that of the Lindley loam the use of farm manure is distinctly profitable and green manures could also be used to advantage in many cases. There is no large supply of phosphorus present in the soil and the use of phosphorus fertilizers will undoubtedly be necessary in the future and might prove profitable now.

MEMPHIS SILT LOAM (31)

The Memphis silt loam occupies the margin of the uplands along the three main river valleys and also along some of the smaller streams. It is found on the tops of narrow ridges and tongues of land and sometimes on the more gentle slopes.

The surface soil is a light-brown to buff-colored silt loam extending to a depth of 15 to 18 inches, underlain by a somewhat lighter colored and more compact silt loam to silty clay loam. The surface soil is sometimes gray in color and it has a loose open texture. The subsoil varies considerably in different places. It is usually a silty clay loam to a depth of 28 inches but below that it occasionally passes into a silty clay. The topography of the Memphis silt loam is gently rolling and the surface drainage is good. The soil washes readily and precautions must always be taken to prevent the occurrence of erosion.

Most of the type is in cultivation, the uncultivated portion being in pasture. The strips of this soil extending between areas of rough land are sometimes too narrow to be cultivated and they are included with the other land in pasture.

All the common farm crops grown in the county produce fairly satisfactory

yields on this soil. Corn does not do as well as wheat and rye. Alfalfa is proving a valuable crop in many cases while clover, timothy and oats are also profitable crops. Near Montrose, strawberries and sweet potatoes are grown to a limited extent and produce valuable crops.

The Memphis silt loam is in need of some special treatments to make it as highly productive as it should be. The organic matter content is low and the soil should receive applications of farm manure. Green manuring would prove profitable in many cases in addition to the use of farm manure or as a substitute for it. The soil is generally acid in reaction and it should be tested and applications of lime made as necessary. Phosphorus is low and phosphorus fertilizers, while showing little value at the present time, will be required in the future.

MARION SILT LOAM (67)

Like the Memphis silt loam this soil occurs along the three river valleys and bordering some of the smaller streams. It occupies the level tops of narrow ridges and less frequently is found in high terrace-like positions where it differs from the typical soil in certain characteristics. The soil is a light-brownish-gray to light-gray silt loam to a depth of 7 to 12 inches. Beneath this surface soil and extending to a depth of 9 inches there is a layer of silty flour-like grayish or whitish material. The subsoil from 16 to 20 inches to 36 inches is a heavy, compact silty clay, gray or grayish-brown in color and becoming mottled with grayish-brown, rusty brown or both at a depth of 24 to 28 inches. The variation mentioned above which is found along Big Sugar creek and Sugar creek is grayish-brown to dark-brown in color and approaches a silty clay loam in texture. At 6 or 8 inches there is a dark-grayish-brown silty clay subsoil which sometimes becomes a yellowish-brown at lower depths. The topography of the Marion silt loam is level to gently undulating. The drainage due to the heavy nature of the subsurface and subsoil material is poor.

Most of the soil is under cultivation but certain small areas which are surrounded by rough, uncultivable lands are in pasture. Wheat, oats, rye, corn and grass are the crops grown on this type, wheat and rye giving the best yields.

In order to make this type more productive the use of an abundance of farm manure, the turning under of green manures, the application of lime and in many cases proper drainage are necessary. Phosphorus is low and must be applied in the future or it might even prove profitable at the present time. Emphasis should be placed particularly on the use of farm manure. Leguminous green manures should also be used to remedy the low organic matter content which is the main reason why soil conditions are unsatisfactory for the best crop production.

GRUNDY CLAY LOAM (68)

The Grundy clay loam occurs only to a small extent in Lee county. Areas are found in the northern and northwestern part of the county in level depressions in the Grundy silt loam. The soil is locally known as "gumbo".

The surface soil to a depth of 10 or 12 inches is a dark-brown to clay loam, underlain by a dark-brown to dark brownish-drab compact, plastic silty clay, which below 18 inches is mottled with dull-brown. From 22 to 36 inches the material consists of a sticky plastic clay or heavy silty clay or light-drab or

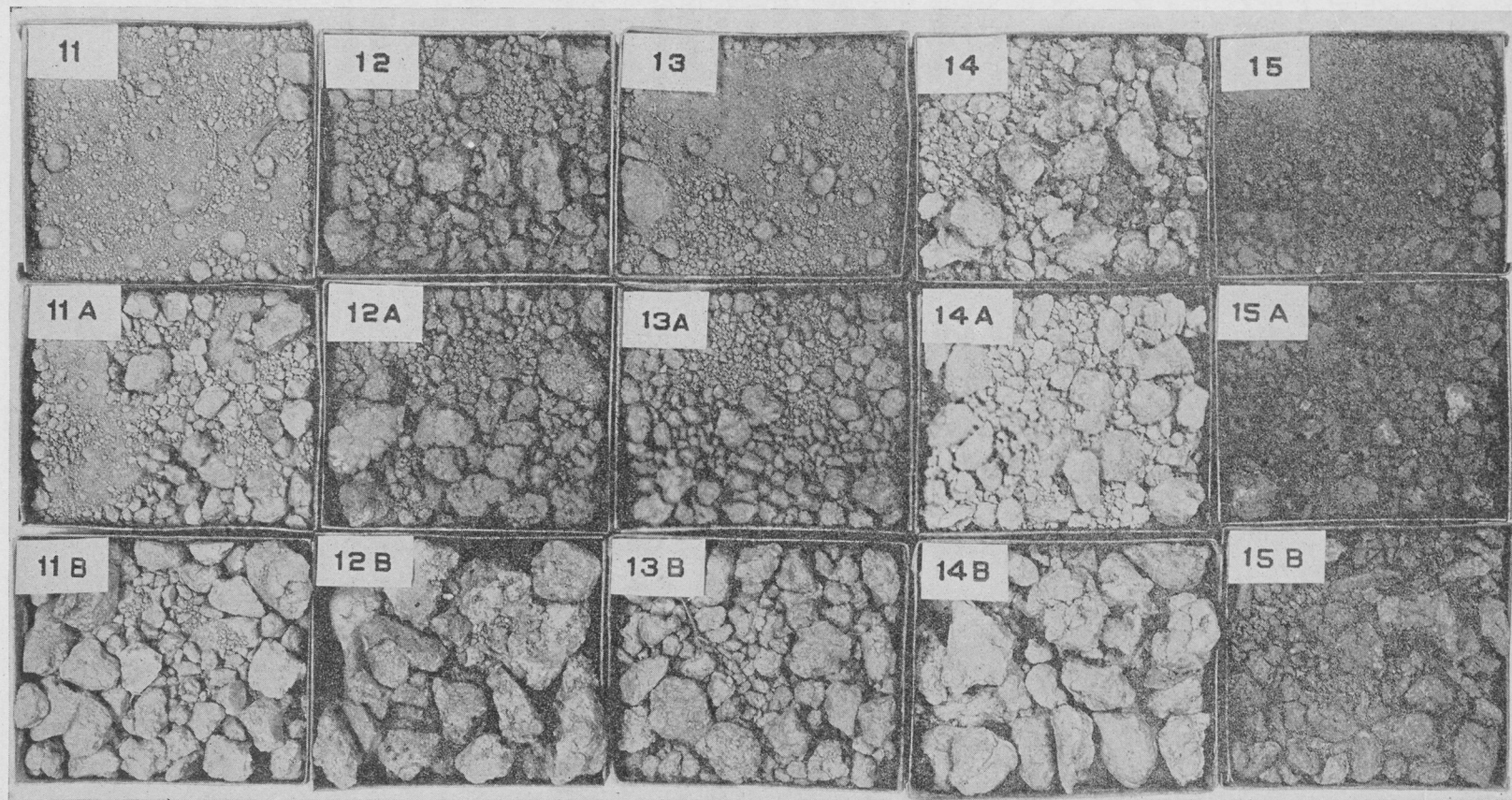


Fig. 5. Surface, subsurface and subsoils of five of the individual soil types in Lee county.

11. Wabash silt loam, colluvial phase
12. Wabash clay

15. Wabash silt loam

13. Grundy silt loam
14. Lindley loam

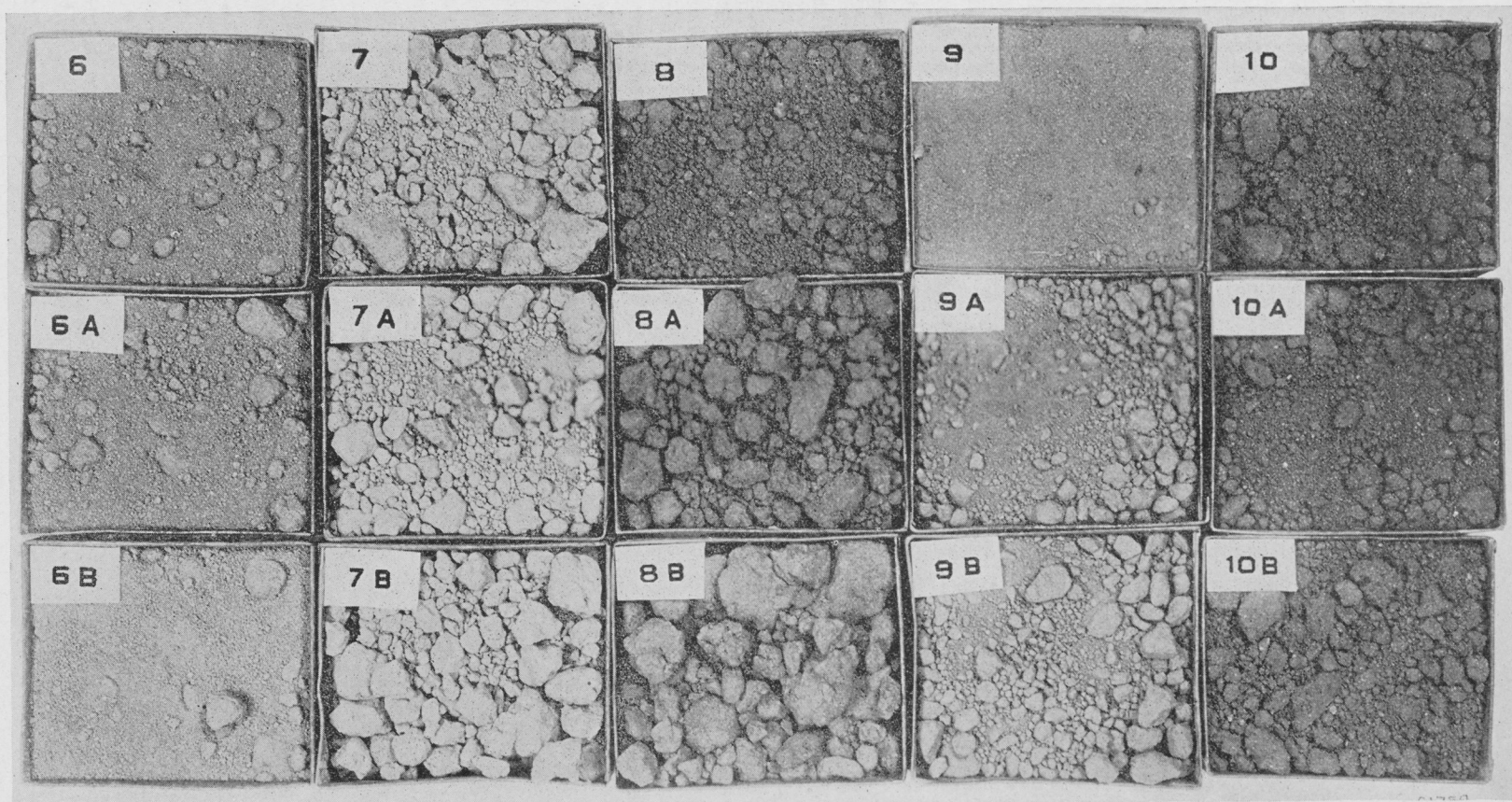


Fig. 6. Surface, subsurface and subsoils of five of the individual soil types in Lee county

6. Wabash fine sandy loam	8. Buckner silt loam
7. Marion silt loam	9. Buckner fine sandy loam
10. Buckner loam	

grayish-drab in color mottled with yellow or rusty yellow. The subsoil is very compact and tenacious and the drainage is poor.

Corn grows well on this soil and clover and timothy also prove successful crops but the growth of small grain is not as satisfactory for they tend to lodge. The needs of "gumbo" are discussed in a previous section of this report but emphasis should be placed here on the fact that drainage is the main treatment necessary for good crop growth. When that is properly accomplished, crop yields will prove satisfactory.

TERRACE SOILS

There are five terrace soils in Lee county all of which are in the Buckner series.

BUCKNER SILT LOAM (36)

This soil occurs on the terraces back from the rivers and along the bluffs. The two largest areas are along Jack creek near Montrose and in the vicinity of Vincennes along the Des Moines river.

The surface soil of this type is a dark-brown to black silt loam which extends to a depth of about 10 inches. The subsoil is a dark-brown to grayish-brown silty clay loam. Below 16 or 18 inches it usually has a yellowish-brown color and approaches a silty clay in texture. Frequently the material is darker in color and heavier in texture below 32 inches. Near the bluffs the soil sometimes is heavier than the typical and at the mouths of small drainage courses there are variations in both color and texture due to the material washed down from the higher areas. The soil is level in topography and the drainage is poor. Tiling and ditching would in many cases make the soil more productive.

The Buckner silt loam is an excellent corn soil and it is well adapted also to small grains and hay.

The soil is in need of organic matter and both farm manure and green manures should be applied. Liming is also necessary in most cases. Phosphorus will be required in the future and may be of value in some cases even now.

BUCKNER VERY FINE SANDY LOAM (69)

This type occurs principally on the Mississippi and Des Moines river terraces. The surface soil is a light brown fine sandy loam to a depth of 15 inches. Below that point it is slightly lighter in color than the surface soil, becoming redder with increasing depth. The texture below 24 inches changes from a fine sandy loam to a silty clay loam. In topography, this soil is level to gently undulating and the drainage is good.

General farm crops and truck crops all do well on this soil. Corn, oats, wheat, alfalfa, clover and sweet potatoes are the chief crops grown.

This soil is particularly low in organic matter and farm manure and green manure should be used in liberal amounts. Lime is necessary in many cases and phosphorus fertilizers will be necessary in the future.

BUCKNER FINE SANDY LOAM (45)

This soil is found on the Mississippi terraces out from the bluffs and close to the area nearest the river. It consists of a light-brown fine sandy loam underlain by material of the same texture, slightly lighter in color and somewhat more compact.

The soil is adapted to general farm crops and to trucking, the larger portion of its area being used for the latter purpose. Corn, alfalfa, oats and wheat are the chief farm crops grown and the principal truck crops are watermelons, sweet potatoes and tomatoes. Trucking generally proves quite profitable.

The application of farm manure and green manures is of special value on this soil as it is low in organic matter. Lime should also be applied and phosphorus fertilizers might prove of value for general farm crops at the present time and will undoubtedly be necessary in the future. Special commercial fertilizers might be used to advantage in the growing of truck crops and brands designed for the particular crops to be grown should be chosen. The rotation of crops should be followed in the case of trucking as well as in general farming.

BUCKNER FINE SAND (46)

The Buckner fine sand occurs on the Mississippi terraces north of Montrose, generally on the margin of the terraces nearest the river. The surface soil is a light-brown fine sand and the subsoil is the same in texture and only slightly lighter in color. In topography this type is undulating and the drainage is good. The sand is often blown badly by the wind forming ridges several feet in height.

Corn and wheat are grown to some extent on this soil but they do not do well. Truck crops, particularly melons, are grown to some extent.

The soil is extremely infertile and for successful crop growth it should receive liberal applications of farm manure and green manures should also be used. These materials will make the soil more retentive of plant food and moisture and with the addition of phosphorus fertilizers and lime good crop yields might be secured. In the growth of truck crops the application of a special brand of commercial fertilizers might also be of considerable value. The use of farm manure and green manures is the treatment primarily needed by this soil and other applications would be of little value without the addition of organic matter.

BUCKNER LOAM (38)

This soil occurs on the Des Moines and Mississippi river terraces, generally back from the streams. It is a dark-brown to black loam to a depth of 10 inches and the subsoil is very similar both in color and texture. Below 30 inches it becomes lighter in color and contains larger amounts of sand. The topography of the soil is level to gently undulating and the drainage is good.

The chief crops grown are corn, wheat, oats, and grass, all of which give quite satisfactory yields. Trucking is also practiced to some extent.

The soil is acid in reaction and in need of lime and the use of farm manure and green manures would also be of value, altho the soil is not as deficient in organic matter as many of the other types. Phosphorus is not extremely low but it will undoubtedly be needed in the future. Where trucking is practiced, the use of special brands of commercial fertilizers might prove of economic value and the greater application of farm manure is also to be recommended.

SWAMP AND BOTTOMLAND SOILS

There are eight bottomland soils in Lee county, representing the Genesee and the Wabash series, and altho small in area, they are quite important soils.

GENESEE VERY FINE SANDY LOAM (70)

This soil occurs on the bottoms along the Des Moines and Skunk rivers and in the Mississippi river bottom near Lost Creek and between Montrose and Keokuk. It also occurs along the more important streams thruout the county.

The surface soil is a light-brown to brown very fine sandy loam and extends to a depth of 15 inches. From that point down to 36 inches the soil is a light-brown very fine sandy loam with a tinge of yellow. The surface soil is somewhat variable in texture, sometimes approaching a fine sandy loam and in other places a silt loam. In some localities small spots of fine to medium sand occur

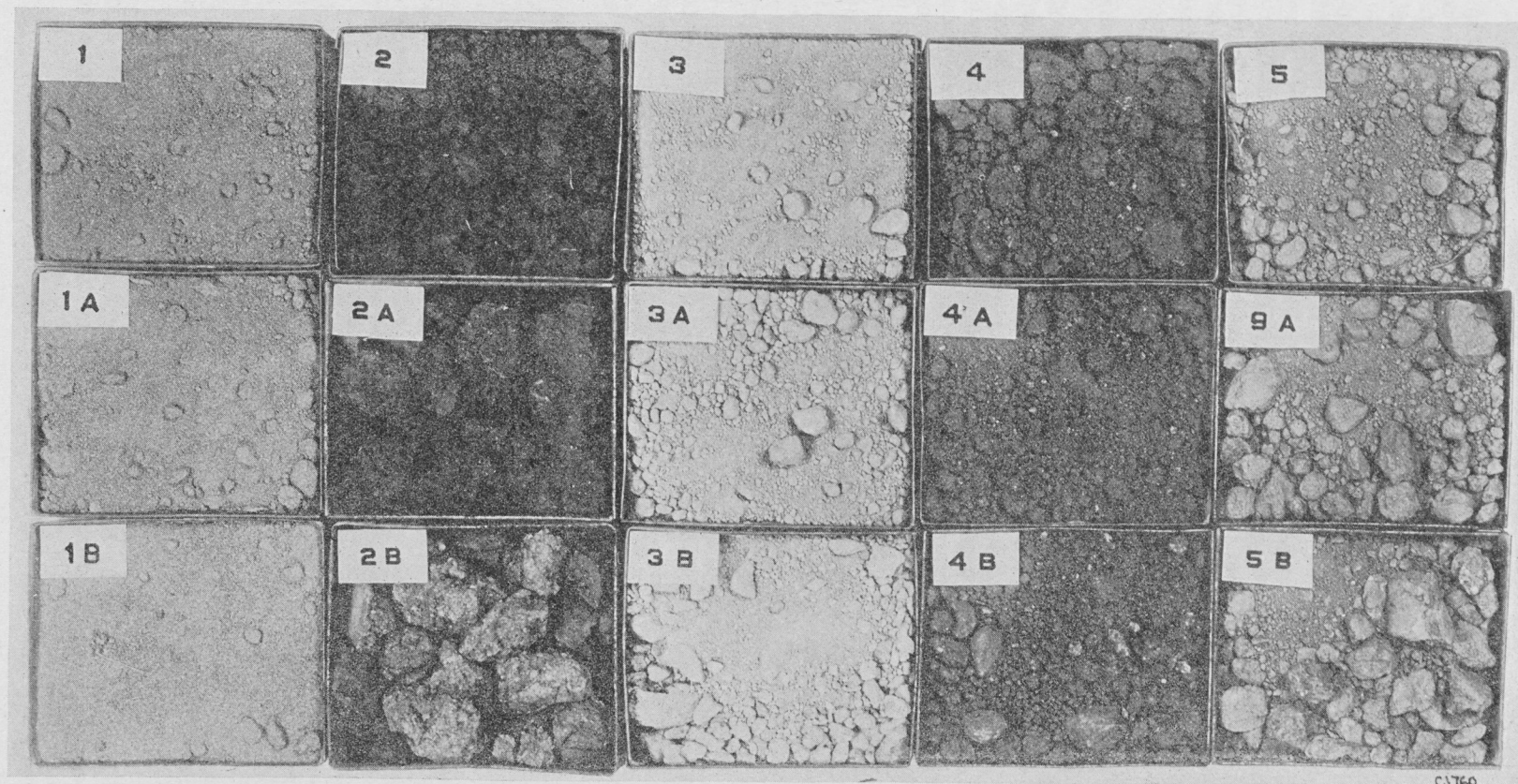


Fig. 7. Surface, subsurface and subsoils of five of the individual soil types in Lee county

1. Buckner fine sand	3. Memphis silt loam
2. Grundy silty clay loam	4. Wabash loam
5. Genesee silt loam	

above the typical soil but they are too small in extent to be shown on the map. The topography of this soil is level to gently undulating and the drainage is good. It is a first bottom soil and is subject to overflow.

Corn, spring wheat, winter wheat, and alfalfa are the principal crops grown, and vegetables thrive on this soil.

In fertility the soil is rather low and for the best crop production liberal applications of farm manure should be made. Green manures would also prove of value in supplementing or replacing the manure. Phosphorus is low and phosphorus fertilizers might prove profitable now and will undoubtedly be necessary in the future. Nitrogen is not present in any considerable amount but the use of leguminous green manure crops will keep the soil supplied with that element. For truck crops besides the use of manure, applications of complete commercial fertilizers might prove decidedly profitable.

GENESEE SILT LOAM (71)

This soil occurs as first-bottom land mostly in the creek valleys but also along the Mississippi near Wever.

The surface soil is a grayish-brown silt loam and extends to a depth of 13 to 15 inches. The subsoil to a depth of 36 inches is a yellowish to grayish-brown silt loam. There are some local variations in the type as it occurs in the Mississippi river bottoms. Sometimes the surface soil approaches a silty clay loam and sometimes sandy loam and in other cases there is a silty clay loam layer in the subsoil extending to a depth of 20 to 30 inches but these variations are small in extent. In topography the soil is level to gently undulating and it is well drained.

General farm crops such as corn, wheat, clover and alfalfa do well on this soil. It is especially adapted to corn and alfalfa altho the latter crop is not grown very extensively as yet. Where this soil is surrounded by land best suited for pasture, it is included in the pasture.

A fair supply of plant food makes this soil quite productive at the present time. The application of farm manure would, however, prove valuable and green manure crops might also prove profitable. Phosphorus is not abundant and must be applied in the future. Tests of phosphorus fertilizers are desirable on this soil.

WABASH SILT LOAM (26)

This soil covers a rather large area in the Mississippi and Des Moines river bottoms.

It is a dark-brown to black silt loam with a depth of 12 inches. The subsoil to 36 inches is a dark-brown to black heavy silt loam to silty clay loam. At about 18 inches it becomes mottled with yellowish-brown and bluish gray and changes in texture to a clay loam. At 28 inches the material is a silty clay and has a pale yellowish-brown color. Sometimes the material below 18 inches remains a heavy silt loam and does not become heavier in texture. The topography of the soil is level but the drainage is good.

General farm crops, particularly wheat, corn, timothy and alfalfa produce good crops on this soil. It also makes good pasture.

Altho fairly well supplied with plant food this soil would be benefited by the application of farm manure. Green manure crops might also prove of value in certain cases and, at any rate, a legume should be included in the rotation to keep up the nitrogen content of the soil. Lime should be added if satisfactory crops of legumes are to be secured. Phosphorus occurs in much larger amounts than on some of the other soils and applications of phosphorus fertilizers are not necessary at present.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

This phase occurs thruout the uplands in the county on the slopes along drainage courses. It lies either below the Lindley loam or directly below the other upland soils.

The surface soil is a gray loam or dark-brown to black heavy silt loam to a

depth of 9 to 16 inches. The subsoil is a dark-brown to black silt loam which changes at 20 inches to a silty clay loam frequently black in color but occasionally dark-brown or yellowish-brown. Below 32 inches the texture sometimes becomes a silty clay. Gravel fragments are generally found in the lower part of the soil section. While the soil occupies gentle slopes in most cases, it occurs in such narrow strips that practically none of it is under cultivation. Its total area is relatively small and the soil is of little importance in the county.

WABASH CLAY (72)

This type occurs in the lowest situations along the Mississippi and Des Moines rivers. It is a dark-brown to black silty clay to clay underlain at a depth of 10 inches by a dark-brown silty clay to clay. Both soil and subsoil are compact and tenacious. In some places along the Mississippi a small percentage of sand is mixed with the surface soil and subsoil.

This soil is poorly drained. A large part of it near Wever is covered by a few inches of water and that area is indicated on the map by swamp symbols. The greater part of the remainder is water-logged and unfit for cultivation. The area along the Des Moines river is cultivated and corn sometimes gives good yields. The type is of little importance agriculturally.

WABASH SILTY CLAY LOAM (48)

This type occurs only in the first bottoms along the Mississippi river, in the vicinity of Wever. The largest area is near the mouth of Skunk river, a narrow strip also extending along the old channel of Lost creek.

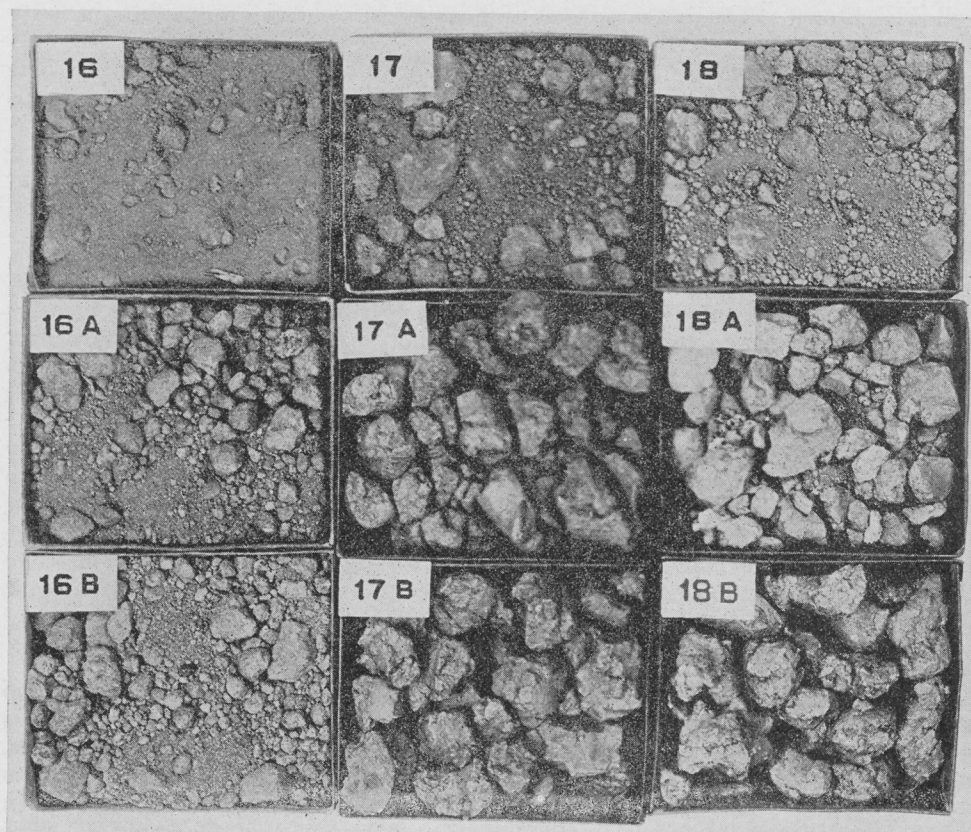


Fig. 8. Surface, subsurface and subsoils of three of the individual soil types in Lee county
 16. Genesee very fine sandy loam 17. Wabash silty clay loam
 18. Putnam silt loam

The surface soil is a dark-brown to black silty clay loam to a depth of 9 inches. The subsoil is a dark-brown to black silty clay which at about 16 inches becomes a silty clay to clay the color being tinged with rusty brown and bluish-gray. Along the river there are some narrow strips or spots, too small to be mapped separately where there is considerable coarse sand mixed with the soil. This soil occurs in low-lying areas of level topography and is not well drained. In many places the installation of tile drains and the use of drainage ditches is necessary and profitable. Much of this soil as well as the Wabash clay is now under water as a result of the construction of the Keokuk dam. The possibilities of diking this land and keeping it drained by pumping are being considered.

General farm crops have yielded well on this soil, corn, wheat, clover, and timothy being the main crops grown. If the excess of water is removed by diking, there would be no difficulty in securing profitable crops. The needs of the soil in such a case would be very similar to those of the other Wabash soils and would include the use of farm manure, green manures, lime and phosphorus.

WABASH FINE SANDY LOAM (62)

This soil occurs in the first bottoms, east and south of Wever and along the Des Moines river. It occupies narrow, elongated ridges and is found to such a small extent in the county that it is relatively unimportant.

The surface soil is a dark-brown to black sandy loam and is underlain at about 12 inches by a slightly more compact fine sandy loam, similar in color. At 20 inches the material becomes distinctly lighter in color, being almost a yellowish-brown. The lower subsoil is heavier in texture approaching a silty clay loam.

This soil is used mainly for corn and wheat or in some cases for pasture. The yields of crops secured in favorable seasons are quite satisfactory. Truck crops especially melons and sweet potatoes might be grown on this soil with profit but as yet they are not produced to any extent.

To make the soil more productive organic matter either as farm manure and green manure, or both, is necessary and to remedy acid conditions lime and phosphorus will be required in the future.

WABASH LOAM (49)

This type occurs only in the Mississippi river bottoms mainly in the vicinity of Wever. It covers a very small area and is not important. It is a dark-brown to black loam underlain at a depth of 16 inches by a brown loam. The soil occurs at a slightly higher elevation than the heavier Wabash soils and is well drained.

General farm crops, especially corn, wheat and oats are grown successfully on this soil and it would probably produce good crops of alfalfa, altho this crop is not grown at present.

The Wabash loam is quite productive but it would be improved in fertility by the use of farm manure and green manures. Lime should also be used to correct the acid conditions which commonly occur. Phosphorus it not abundant and for permanent fertility phosphorus fertilizers should be applied.

UNION STONY LOAM (73)

This is the only residual soil in the county and it occurs on some of the steep slopes leading to the Skunk, the Des Moines, and the Mississippi rivers. It is also found in the hollows or draws leading back short distances from these slopes.

It is a grayish-brown to reddish-brown silt loam to a depth of 6 to 10 inches underlain by a rather compact silty clay of a distinctly red to reddish-brown color. Rock fragments occur on the surface and thruout the 3-foot section. The surface soil is often washed away and a silty clay loam or silty clay is exposed. Practically none of the soil is in cultivation as it is too steep and stony and it is of no importance agriculturally.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied are problems which are met constantly on the farm today.

To enable every Iowa farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in coöperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins, as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green

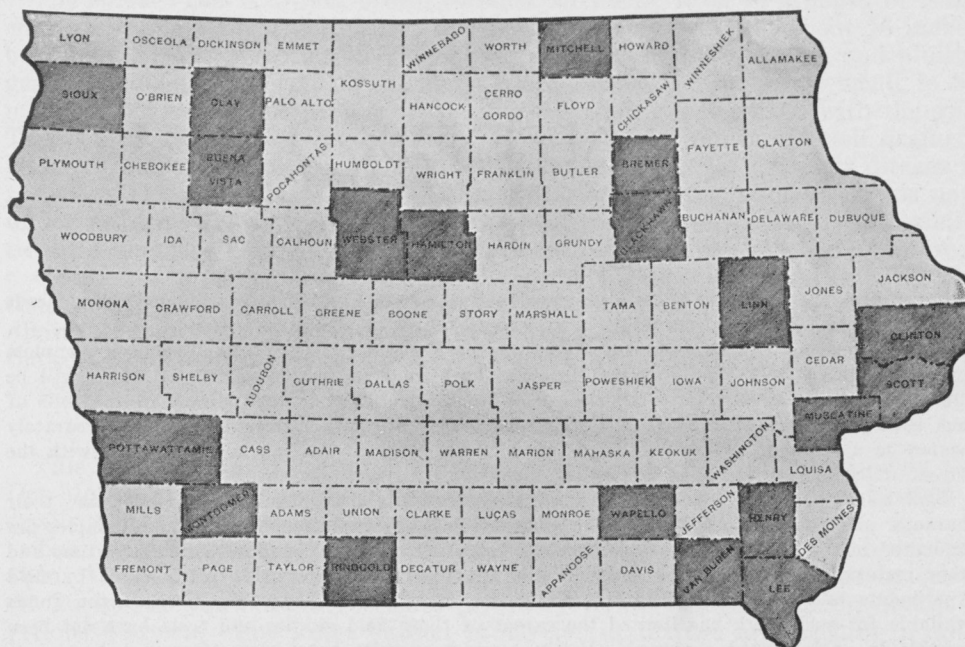


Fig. 9. Map of Iowa showing the counties surveyed

manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced," as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true in Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage in this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proven of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished care should always be taken that the soil be in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growing of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated *as they should be*, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil there is a large loss of fertility, and if the entire crop is removed and no return made, the

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (NaNO_3)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Food Plant
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain	75 bu.	75	12.75	14	\$12.00	\$1.53	\$0.84	\$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.52	5.40	17.00
Alfalfa hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably the loss of plant food.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about \$30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large,

* Bulletin 150 Iowa Agricultural Experiment Station.

there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements which are likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for crop production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought by thorough cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drought may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amount of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop, if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotations. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be

hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotation should contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated, and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this Station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions given in bulletin 151, referred to above.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one to two tons per acre.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the accompanying map.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa to-day, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching action in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. The climatic conditions,

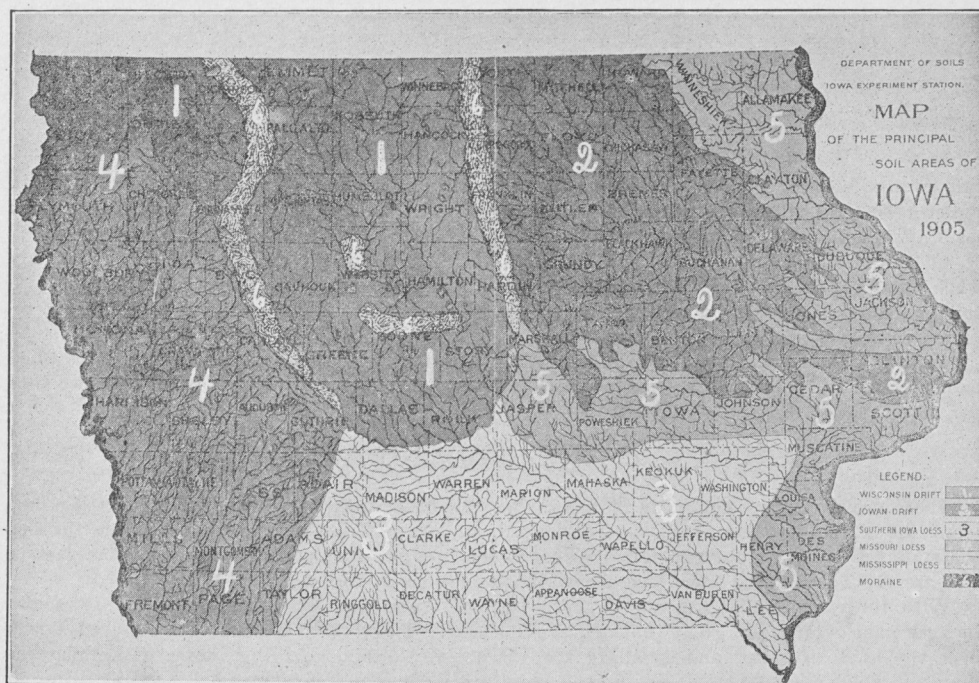


Fig. 10. Map showing the principal soil areas in Iowa

topography, depth and character of the soil, chemical and mechanical composition, and in short all the factors which may affect crop production, must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils, and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large soil areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows¹ according to the Bureau of Soils:

Organic Matter { All partially destroyed or undecomposed
vegetable and animal material.

Inorganic Matter { Stones—over 32 mm.*
Gravel—32—2.0 mm.
Very coarse sand—2.0—1.0 mm.
Coarse Sand—1.0—0.5 mm.
Medium Sand—0.5—0.25 mm.
Fine Sand—0.25—0.10 mm.
Very fine Sand—0.10—0.05 mm.
Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The different general groups of soils by types are indicated thus by the Bureau of soils:²

Peats—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 per cent of organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 per cent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.

Silty Clay Loams—20 to 30 per cent clay and more than 50 per cent silt.

Clay Loams—20 to 30 per cent clay and less than 50 per cent silt and some sand.

Silt Loams—20 per cent clay and more than 50 per cent silt mixed with some sand.

Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

* 25 mm. equals 1 in.

¹ Bur. of Soils Field Book.

² 1 C.

Sandy Clays—20 per cent silt and small amounts of clay up to 30 per cent.

Fine Sandy Loams—More than 50 per cent fine sand and very fine sand mixed with less than 25 per cent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 per cent.

Sandy Loams—More than 25 per cent very coarse, coarse and medium sand; silt and clay 20 to 50 per cent.

Very Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent fine sand, less than 20 per cent silt and clay.

Coarse Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent of other grades, less than 20 per cent silt and clay.

Gravelly Loams—25 to 50 per cent very coarse sand and much sand and some silt.

Gravels—More than 50 per cent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHOD USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all the soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available it is the first duty of the field party to prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.